

## A $\gamma$ Doradus star campaign

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### Abstract.

We report on the results from a large photometric campaign on thirty five  $\gamma$  Dor star candidates undertaken at the Institute of Astronomy of the University of Leuven in the framework of the Flanders – South-Africa grant. An overview of the data, as well as the results of the analysis of the obtained time series are presented, the main conclusion being that nine stars are thought to be multiperiodic  $\gamma$  Dor stars and eight monopерiodic. We also performed a photometric mode identification for two stars of the sample by comparing the amplitude ratios in the different passbands of the Geneva photometric system. Both stars seem to pulsate in non-radial modes of degree  $\ell = 1$ .

## 1. Introduction

This story starts with Cousins (see the review by Kilkenny – these proceedings) & Warren’s (1963) suggestion of having found photometric variability in the F0 V star  $\gamma$  Dor. Cousins (1966) himself confirmed unambiguously his discovery of the variability in  $\gamma$  Dor, the star that later would become the prototype of a new class of pulsating stars. Much later, Cousins (1992) was able to detect two close periods in  $\gamma$  Dor : 0.7570 d & 0.7334 d.

Balona et al. (1996) undertook a very detailed photometric and spectroscopic follow-up study of  $\gamma$  Doradus and found one additional frequency. Moreover, they refined the frequency values to  $1.32098 \text{ d}^{-1}$ ,  $1.36354 \text{ d}^{-1}$ ,  $1.47447 \text{ d}^{-1}$ . For illustrative purpose, we show in Fig. 1 the phase diagrams for the three detected frequencies of both the photometric and spectroscopic data of Balona et al. (1996). Earlier on, Balona et al. (1994) already proposed  $\gamma$  Dor to be a member of “a new class of non-radial gravity-mode pulsators”. With their 1996 paper, Balona et al. left no longer doubt about the cause of  $\gamma$  Dor’s variability:

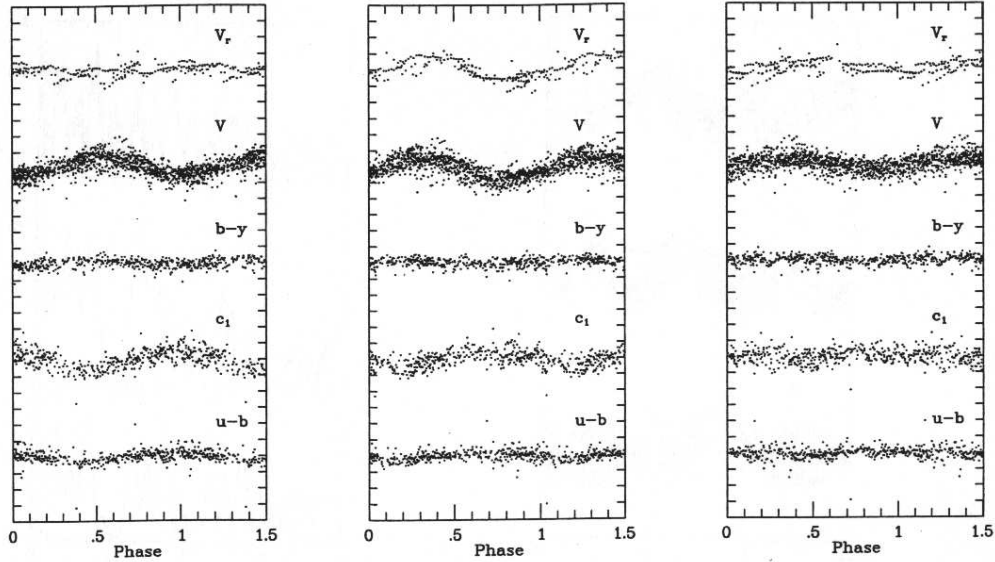


Figure 1. Phase diagrams of the radial-velocity, light and colour variations of the prototype of the class of  $\gamma$  Dor stars for the frequencies  $1.32098 \text{ d}^{-1}$  (left),  $1.36354 \text{ d}^{-1}$  (middle),  $1.47447 \text{ d}^{-1}$  (right). Figure taken from Balona et al. (1996) with permission.

the radial-velocity variations excluded binarity, while spot models were also excluded since: 1) they required a too large differential rotation, 2) the periods were too stable, and 3) there was no phase difference between the radial-velocity and light maxima. It therefore seemed unavoidable to conclude that  $\gamma$  Dor pulsates multiperiodically, with pulsation periods an order of magnitude longer than those of pressure modes.

Meanwhile, several comparison stars for other variables turned out to have similar variability to  $\gamma$  Dor:

- HD 164615 (Burke et al., 1977);
- HD 55892 (Hensberge et al., 1981);
- four variables in NGC 2516 (Antonello & Mantegazza, 1986);
- 9 Aur (Krisciunas & Guinan, 1990);
- HD 111828 (Mantegazza et al., 1991);
- HD 224638 & HD 224945 (Mantegazza & Poretti, 1991);.

This led Krisciunas & Handler (1995) to publish a list of 17 candidate  $\gamma$  Dor stars. Since the publication of the list by Krisciunas & Handler, several additional candidates were found from ground-based photometry (Henry, 1995, 1999;

Breger et al., 1997; Kaye et al., 1999; among others). Presently, an updated list is maintained by Handler at <http://www.sao.ac.za/~gerald/gdorlist.html>.

It should be noted that the periodic variability of only very few stars is illustrated by phase plots of the quality shown in Fig. 1. For most stars the scatter is considerably larger.

The cause of the non-radial gravity modes is still a matter of debate. Guzik et al. (2000) have proposed an excitation mechanism, but this certainly is not generally accepted (see, e.g., Wu 2002; Löffler 2002). It is therefore of importance to find as many members as possible and to derive their basic physical stellar parameters, besides their frequencies and mode identification.

One of the early ideas about the general properties of  $\gamma$  Dor stars is that such pulsators would be young. This suggestion was based on the fact that circumstellar matter was discovered around some member stars, among which is  $\gamma$  Dor itself. Inspired by this proposal, searches for  $\gamma$  Dor stars in clusters of different ages were undertaken. Krisciunas & Patten (1998) discovered 2  $\gamma$  Dor candidates (out of 15 stars) in M 34 (age  $\simeq 195$  Myr), while Zerbi et al. (1998) came up with 8 candidates (out of 44 stars) in NGC 2516 (age  $\simeq 107$  Myr). An enormous effort in this respect was done by Martin (2000), who checked 149 stars in 9 clusters. She found only 3  $\gamma$  Dor stars: 2 in the Pleiades (age  $\simeq 83$  Myr) and 1 in Coma Ber (age  $\simeq 490$  Myr). The conclusion therefore must be that current studies do not reveal a clear relationship between age and the  $\gamma$  Dor phenomenon.

The FlanSA  $\gamma$  Dor campaign found its origin at the IAU General Assembly in Kyoto in 1997, when CA convinced LE to come to Leuven for a scientific visit to search in detail for new  $\gamma$  Dor stars in the HIPPARCOS data base. LE's visit resulted in a chain of initiatives with respect to the study of  $\gamma$  Dor stars, which we highlight in this paper. First we report on the status of the FlanSA  $\gamma$  Dor campaign in Section 3, after having highlighted the contribution into this field by the HIPPARCOS mission (Section 2). The analyses of the time series are described in Section 4, while an attempt to identify the modes in two stars is explained in Section 5. We end this paper with future prospects and additional current studies of  $\gamma$  Dor stars at the Institute in Leuven and worldwide.

## 2. The Contribution of the HIPPARCOS mission

We recall that the HIPPARCOS photometry provides a homogeneous all-sky survey down to  $V$  magnitude 7.3-9.0 (depending on the galactic latitude and the spectral type of the observed star). The HIPPARCOS satellite took 13 million photometric measurements of about 118 000 stars over a period of 3.3 yr (52 000 stars are from the survey and 66 000 stars were selected objects). The HIPPARCOS photometry proved to be very useful to reveal large numbers of new variables of many different kinds (see ESA 1997: fields H6, H49-54 of the main catalogue and volumes 11 and 12). In specific cases the number of known variable stars increased dramatically, e.g. the number of Slowly Pulsating B stars increased nearly by a factor 10 (Waelkens et al. 1998).

HIPPARCOS has rather good detection capabilities for determining correctly the characteristic periods of  $\gamma$  Dor stars (0.5-3 d). The sampling does not suffer from the alias problems of Earth observations for such stars. Indeed, the spectral windows of HIPPARCOS and ground-based data show very different patterns.

However, the precision of photometric individual measurements degrades quite rapidly for fainter stars (although more time was allocated to observe them), impeding the unambiguous variability detection of fainter objects.

Another difficulty with the HIPPARCOS data occurred specifically for  $\gamma$  Dor stars, since their variability behaviour is not always strictly periodic. This, in combination with the rather low density of data points of the HIPPARCOS sampling, prohibited an easy search for new candidate members of the class. For instance, when we compare the bona-fide member list (which contained 13 stars in the version of 2000) and the HIPPARCOS catalogue, we find that all stars listed were measured by HIPPARCOS and were classified as follows: 4 stars are in the Variability Annex as periodic variables, one star as unsolved variable, three stars are flagged as microvariable, four are without classification and one flagged as constant. A remark worth making is that the four stars in the Periodic variables of the Variability Annex have periods at the short end of the interval 0.5-3 d.

Eyer (1998) and Eyer & Grenon (1998) did a selection of  $\gamma$  Dor candidates, which was made from the published Periodic variable star Annex from the HIPPARCOS catalogues (volume 11 and 12, ESA 1997). This preliminary study was based on stars which had precise parallax and colour  $B - V$ . In the HR diagram, there was clearly at the cool edge of the region occupied by the  $\delta$  Scuti stars a very clumped group of stars with periods and amplitudes compatible with the  $\gamma$  Dor stars and thus these were declared good candidate  $\gamma$  Dor stars.

Aerts, Eyer & Kestens (1998), in an effort to be more general and to settle better the case of membership, performed a multivariate discriminant analysis by using Geneva photometric indices in order to determine the physical properties of the stars. As a supplementary test, all stars were checked against multiperiodicity. The stars were drawn from the Periodic variable star Annex. The two first studies listed the name of 29 stars identified with HIPPARCOS photometry (three being redundant with the list of Handler & Krisciunas 1997).

Because of the sometimes irregular nature of  $\gamma$  Dor light curves, candidates could have been rejected from the Periodic variable Annex by the HIPPARCOS groups analyzing and producing the catalogues. Handler (1999a) decided to go through the HIPPARCOS data once more, but looked at the periodic variability Annex as well as at the Unsolved catalogues. He also widened the criteria of acceptable spectral types. His analysis permitted the addition to the list of 31 non-redundant prime candidates.

We recall here that only 6 years ago, the number of total objects was 17 (6 bona fide members and 11 candidates – Krisciunas & Handler 1995). As we can see from the successive lists provided in publications and/or on the Internet, this field has undergone intense studies. At the time of this oral presentation there were 13 bona-fide members listed by Handler, and the number of candidates amounted 122<sup>1</sup>.

We assisted in the explosion of the number of candidates and therefore undertook the initiative of settling the origin of the variability for each candidate

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<sup>1</sup>Since then the list maintained by Gerald Handler has been updated, and we have the following progression of respectively bona fide members and candidates for different years 1995: (6, 11); 1997: (9, 16); 2000: (13, 122); 2001: (24, 120).

$\gamma$  Dor star. This somewhat unrewarding task of removing objects from a list of potentially very exciting stars requires extensive new photometric campaigns. The Institute of Astronomy in Leuven decided to undertake this effort. C. Aerts took the initiative of applying for several weeks of observing time in South Africa in the framework of the FlanSA project. L. Eyer became the driving force of the planning and exploration of the observing time allotted in Sutherland. At the same time the 1.2-m Swiss at La Silla was used to monitor each of the candidates spectroscopically. Furthermore the Leuven 1.2-m telescope Mercator (a twin of Euler) at La Palma has become operational (since a few months prior to this writing) and is currently used to monitor the northern  $\gamma$  Dor candidates photometrically in the seven-colour Geneva system. We here report on the results derived from the data gathered in South Africa.

### 3. The observational Campaign at SAAO

The time allocated for this project was 15 weeks spread over one year (from 1999 October to 2000 September) in order to observe 35 stars on the 0.5-m telescope located in Sutherland. The observations were done in the  $B$ ,  $V$ ,  $I$  bands in the sequence  $I - V - B - B - V - I$  (30-s exposures in each filter) and then sky measurements in  $I - V - B$  (10 s in each filter). The whole sequence for observing an individual star took about 3 min and 50 s.

The photometry obtained is differential. Two stars were chosen as comparison stars for each programme star. Their selection was done using HIPPARCOS epoch photometry. Particular attention was paid to remove stars with peculiar chemical composition. For those stars the variation of the luminosity is a function of the wavelength. More precisely, for the cooler Ap stars, the variations can be in anti-phase in blue and red light and the signal is washed out in a broad band filter like the  $H\beta$  filter. Therefore the star appears to be a constant. The physical reason of this is that the blocking effect is more severe in the blue, while the re-emission is in the red for the cool Ap stars (in the case of hot Ap stars the blocking effect is in the ultraviolet and the backwarming in the visible). The comparison stars were generally chosen to be at a distance less than  $7^\circ$  and of similar magnitude. Furthermore, one comparison star was chosen to be slightly bluer than the programme star and the other slightly redder.

The measurements consisted of three block sequences of  $A - P - B$  where  $P$  is the programme star and  $A$  and  $B$  are the comparison stars. Typically a star was measured 2-4 times per night. However the sampling was sometimes denser with short sequences  $A - P - B - P - A \dots$  (where  $P$  is the programme star and  $A, B$  the two comparison stars) in order to be able to distinguish periods of  $\delta$  Sct stars from periods of  $\gamma$  Dor stars.

Some tests were also done to take photometry only in two bands at the beginning or end of the night (before and after the astronomical night) focusing on only one star.

#### 3.1. Weather conditions

The campaigns in Sutherland suffered from relatively bad weather. Normally the fraction of photometric nights is about 55%, while we had about 40–45%. There were a few exceptional and rare events:

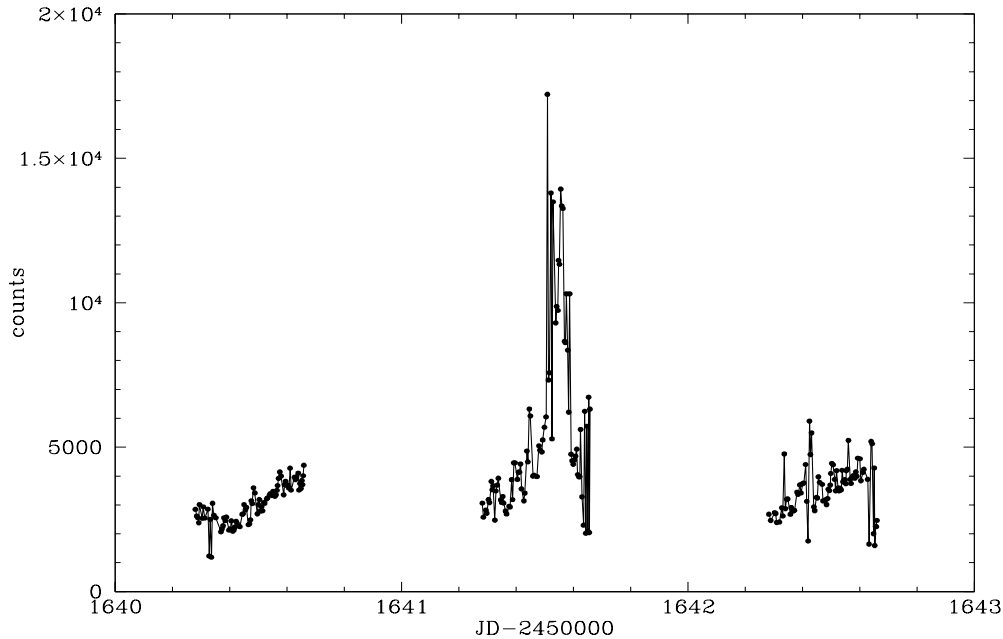


Figure 2. On the night of 2000 April 6-7, a beautiful Aurora Australis occurred. The sky counts in the V band are represented for three nights. The variation of the sky counts due to the aurora reaches nearly 2 mag. The following nights are also slightly perturbed.

- the tail of the bad weather causing the tragic flood in Zimbabwe surprisingly reached Sutherland,
- a beautiful Aurora occurred, which had the sad effect of rendering void a large part of a night. The time scale of the light variability caused by this aurora is short as seen in Fig. 2. We recall here that Sutherland is not very far South (latitude is  $-32^\circ$ ).

### 3.2. The observers

We give below by affiliation the list of observers, with (in parentheses) the number of weeks observed. From the Katholieke Universiteit Leuven (KUL): L. Eyer (6), P. De Cat (3), from the South African Astronomical Observatory (SAAO): F. van Wyk (2), G. Handler (1), from the University Cape Town (UCT): M. Müller (2), M. Hempel (1). The people having no experience with the 0.5-m received an introduction by either D. Kurtz or G. Handler.

### 3.3. The programme stars

The initial target list contained thirty-seven stars. However, at the beginning of the observing run two stars were removed from the list thanks to the cross-check of the list by G. Handler (1999b). Their  $V$  magnitudes range from 5.3 to 9.5. Five stars needed to be observed with neutral density filters. The spectral types range from A1 to F4, but most stars are classified as F0 or F2. Altogether

105 stars (programme stars and comparison stars) were observed during the observing run. Finally we note that twenty-six of the stars are being measured with the Echelle spectrograph CORALIE attached to the Swiss Euler telescope located at La Silla. The spectral analysis is still in progress, so we will not refer to it here.

Thirty stars were analyzed in total in the following section. The number of observations per star varies between 14 and 97 in the  $V$  band. Seventeen stars were from the lists of Eyer (1998) and Aerts et al. (1998), eleven from Handler (1999a), one from the bona fide member list, and one from Paunzen et al. (1998).

#### 4. The analysis of the time series

The analysis of the time series was performed by F. Bouckaert in the framework of his master thesis in Leuven and was supervised by J. Cuypers and C. Aerts. For those stars which are also present in the Geneva data base, a general comparison was done with Geneva photometry. For all stars, the variability in the South African data was cross-checked also with the HIPPARCOS data and with results from the literature, whenever possible. There is a point worth mentioning here: in Simbad the origin of the discovery of the variability is not reported and sometimes it is difficult to trace back the source of the claimed variability and subsequently check more carefully the data.

The period searches were done with different programs and methods, both based on the PDM technique and on Fourier analysis. Moreover, we used the programme developed by J. Cuypers which fits simultaneously several frequencies. Special emphasis was put on the search for multiperiodicity for every star.

The stars were classified in several categories: multiperiodic  $\gamma$  Dor stars, singly periodic  $\gamma$  Dor stars, non- $\gamma$  Dor stars ( $\delta$  Sct stars, eclipsing binaries) and dubious cases. We now sum up the results for each of these categories.

##### Multiperiodic $\gamma$ Dor stars

Our analysis resulted in the classification of 9 targets as multiperiodic  $\gamma$  Dor stars: HD 12901 (HIP 9807), HD 34025 (HIP 24215), HD 48501 (HIP 32144), HD 65526 (HIP 39017), HD 110606 (HIP 62105), HD 112685 (HIP 63372), HD 135828 (HIP 74825), HD 206481 (HIP 107443), and HD 209295 (HIP 108976).

As an illustration, we present in Fig. 3 the data for the star HD 112685. It is clearly multiperiodic, with the periods 0.623 d (main period), 0.349 d and 0.737 d. Although we have far fewer data points, the quality of the phase diagrams is similar to the one of the prototype shown in Fig. 1. The HIPPARCOS periodic variable Annex quotes a period of 0.600 d for this object. The phase diagrams of the eight other stars are similar to the ones shown here for HD 112685.

##### Singly periodic $\gamma$ Dor stars

There are 8 stars classified as monoperiodic  $\gamma$  Dor stars: HD 10167 (HIP 7649), HD 14940 (HIP 11192), HD 26298 (HIP 19383), HD 40745 (HIP 28434), HD 111709 (HIP 62774), HD 112934 (HIP 6349), HD 187028 (HIP 97590), and HD 197451 (HIP 102329).

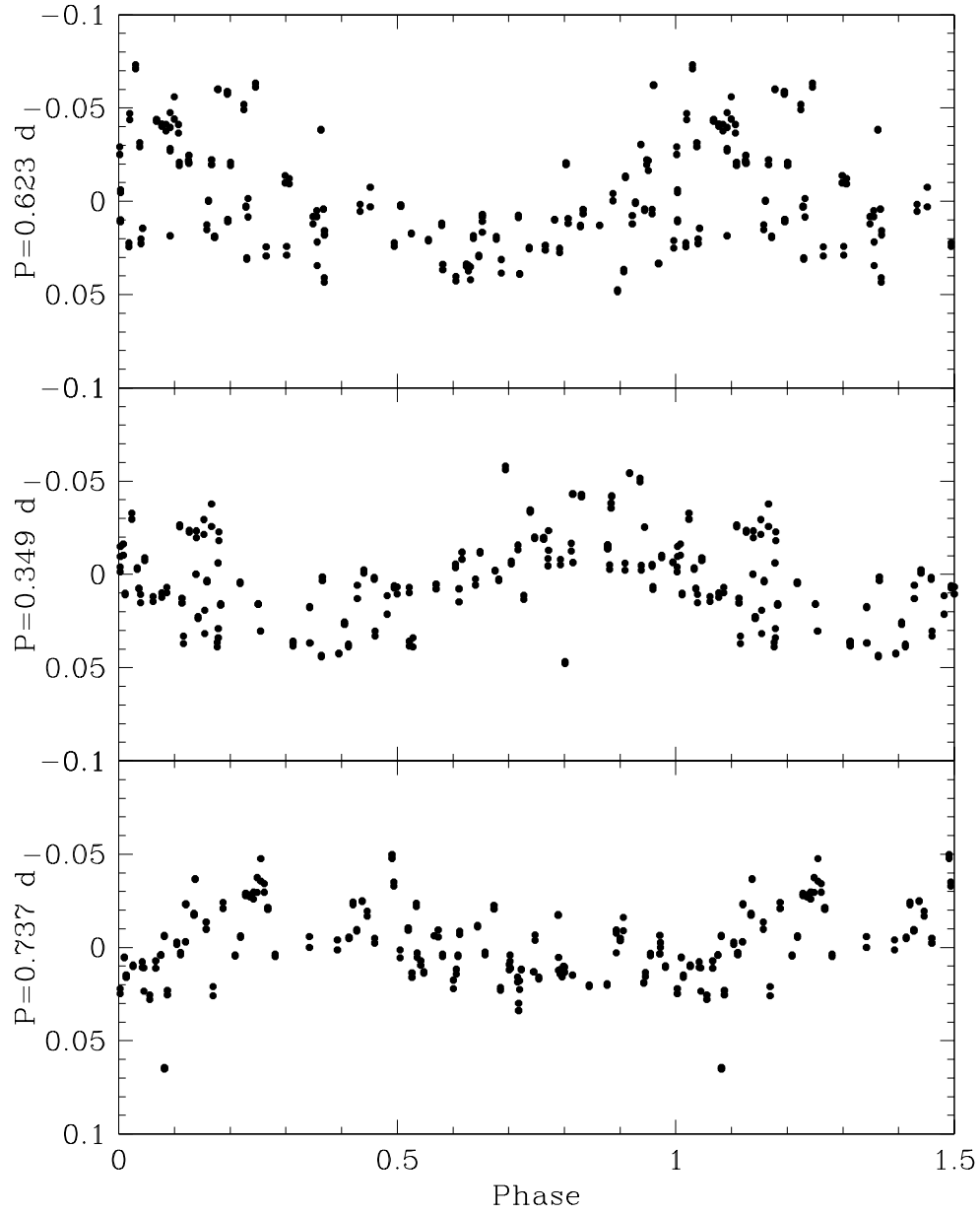


Figure 3. A multi-periodic  $\gamma$  Dor star, HD 112685 (HIP 63372).



One might be tempted to conclude that about half of the  $\gamma$  Dor stars turn out to be monoperiodic. However, we note that the stars of small amplitude will have a tendency to be classified as monoperiodic  $\gamma$  Dor stars for statistical reasons, particularly when a relatively small amount of data is available. The monoperiodicity of our targets does not necessarily imply that the fraction of multiperiodic  $\gamma$  Dor stars is effectively higher at higher amplitude.

### Eclipsing binaries

HD 41448 (HIP 28778), HD 81421 (HIP 46223), and HD 85964 (HIP 48580) are thought to be eclipsing binaries. This conclusion was drawn because of the difference in depth of successive minima in the light curve, which is typical for EB type eclipsing binaries. The phase plots of the three stars are shown in the Fig. 4.

Handler (2001) would classify the star HD 41448 as a  $\gamma$  Dor star, though. Its light curve does indeed also support that interpretation since it shows a clear sign of multiperiodicity. It remains to be confirmed if the unequal minima are true, or merely a consequence of the multiperiodicity. It may very well be that this star is a binary with a  $\gamma$  Dor star as a component. The spectra currently taken by CORALIE will probably resolve the ambiguity.

### $\delta$ Sct stars

There are two objects classified as  $\delta$  Sct stars: HD 125081 (HIP 69848) and HD 181998 (HIP 95358). The spectrum for the former star is shown in Fig. 5. The main frequency is  $6.4941 \text{ d}^{-1}$ . For the latter object our analysis is in contradiction with the conclusion of Handler (1999b). We find evidence for a frequency of  $6.742 \text{ d}^{-1}$ , while Handler lists a typical  $\gamma$  Dor frequency of  $0.7496 \text{ d}^{-1}$ . Very probably both frequencies are aliases of each other.

### Dubious cases and additional comments

For three additional stars our study did not lead to firm results, mostly because of a lack of data. This concerns HD 171813 (HIP 91412), HD 197187 (HIP 102217), and HD 216910 (HIP 113402). For the latter two stars our analysis does not confirm the previously published periods found in HIPPARCOS (those two stars also have few measurements).

There is one star which shows longer term behaviour in our data: HD 27377 (HIP 20036) for which we find a frequency of  $0.100 \text{ d}^{-1}$ . This result is in conflict with Handler (1999a), who reports the two frequencies  $0.3511 \text{ d}^{-1}$  and  $0.548 \text{ d}^{-1}$  from the HIPPARCOS data. Additional data are needed to understand the variability pattern for this object. For 4 additional studied stars no conclusions were reached.

All the results presented here will be reviewed and published with the addition of CORALIE spectra which are currently being gathered and analysed. Special care will be taken for the claim of eclipsing binaries and for the distinction between EW eclipsing binaries and monoperiodic  $\gamma$  Dor stars.

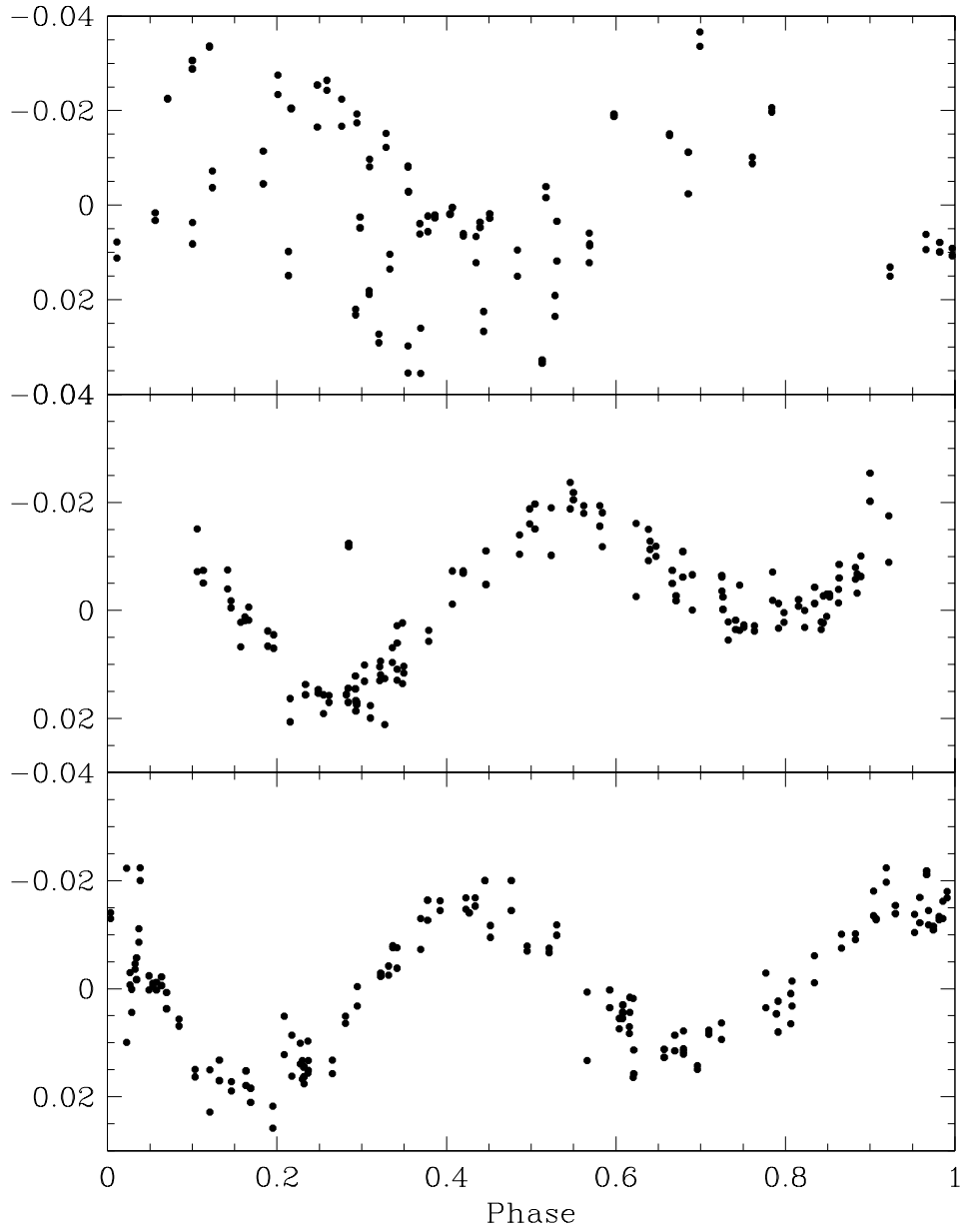


Figure 4. The phase diagrams of the three eclipsing binaries HD 41448, HD 81421 and HD 85964 (top to bottom).

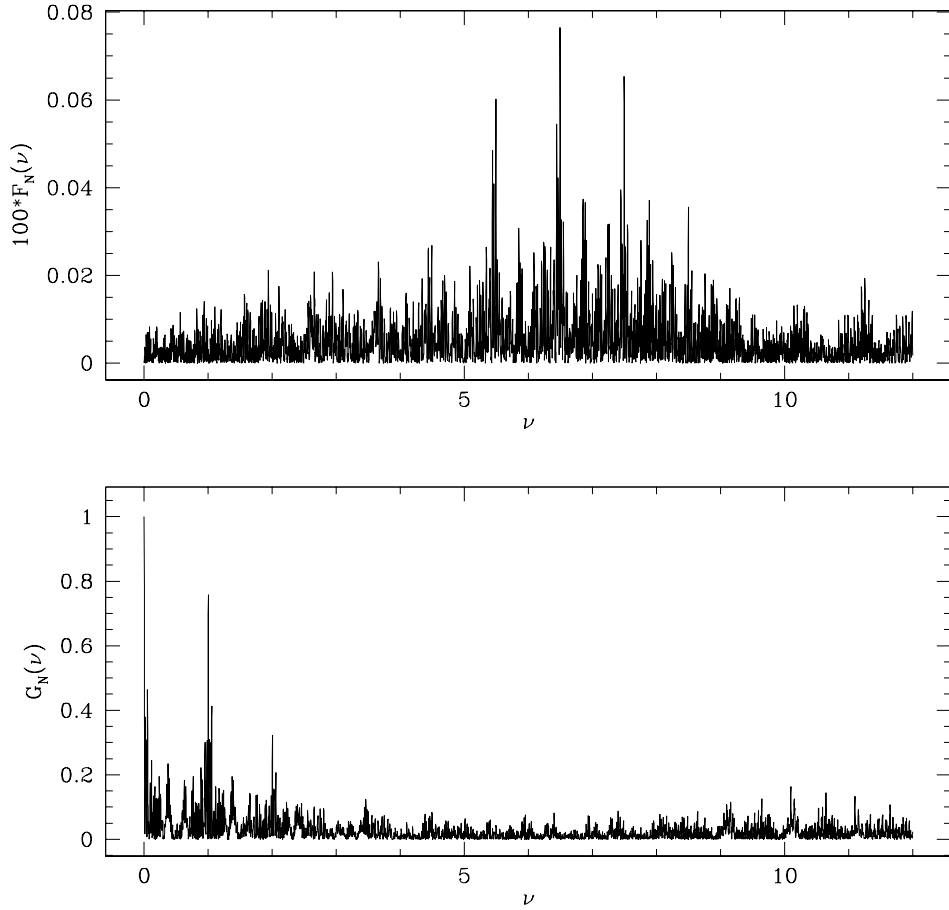


Figure 5. Power spectrum (up) and spectral window (down) for the star HD 125081. Frequencies are expressed in cycles per day.

## 5. Photometric Mode identification

For two of the target stars, we also have extensive Geneva data at our disposal. As this leads to amplitudes at seven different wavelengths, we decided to try to identify the pulsation modes in these two  $\gamma$  Dor stars. This work was performed by M. Van Loon in the framework of her Master's thesis and was supervised by C. Aerts.

The goal of the work is to identify the non-radial pulsation modes thanks to the different behaviour of the pulsation as observed through different filters. This photometric method is able to discriminate between different (low) degrees  $\ell$  but cannot derive the azimuthal number  $m$ . For a review of the method of photometric mode identification we refer to Garrido (2000). Although the method has severe limitations because of the inherent different results introduced

Table 1. Physical properties of two  $\gamma$  Dor stars

HD	HIP	$T_{\text{eff}} [K]$	$\log(g)$	$[M/H]$	$M [M_{\odot}]$	$R [R_{\odot}]$
12901	9807	7000	4.5	-0.4	1.5	1.2
48501	32144	7000	4.5	-0.1	1.5	1.1

by using different atmosphere models (see the discussion by Garrido), we applied it to the two stars to get a crude idea about the pulsational degree. As there exists currently no real overall accepted excitation mechanism, any estimate of the observed degree is welcome for as many stars as possible.

Only two stars were considered, HD 12901 and HD 48501, since these are the only ones for which we have data in many filters. They were measured in the seven filters of Geneva photometry ( $U$ ,  $B$ ,  $B1$ ,  $B2$ ,  $V$ ,  $V1$ ,  $G$ ). These two stars were already discussed in the article by Eyer & Aerts (2000), who classified them as new  $\gamma$  Dor stars. Bouckaert found three frequencies for each of the two stars:  $1.21564 \text{ d}^{-1}$ ,  $1.39595 \text{ d}^{-1}$ , and  $2.18374 \text{ d}^{-1}$  for HD 12901 and  $1.29054 \text{ d}^{-1}$ ,  $1.09408 \text{ d}^{-1}$ , and  $1.19924 \text{ d}^{-1}$  for HD 48501.

The physical parameters of both stars were determined from the calibration by Künzli et al. (1997), making use of the stellar models published by Schaller et al. (1992) and Schaerer et al. (1993). They are displayed in Table 1. We remark that the stars are nearly twins, except for their metallicity. Indeed their temperature, gravity, mass, and radius are equal within the uncertainty induced by the method of determination. The time series analysis reveals also that the detected frequencies are rather similar, as well as their amplitude ratios. One expects therefore, their pulsation modes to be of similar nature as well.

The method of Heynderickx et al. (1994) was used for the mode identification. With this method, the amplitude ratios with respect to the  $U$  filter are concerned. The choice of the  $U$  filter is arbitrary, but was chosen in this method because it was designed originally for applications to  $\beta$  Cep stars, which have by far the largest amplitude in the bluest filter. The main hypotheses and ingredients of the method are:

- the unknown non-adiabatic effects are taken into account by a free parameter, which is determined such that the difference between observed and theoretical amplitudes is minimal (same as in the method by Garrido),
- rotational effects are completely neglected,
- the phase difference between the light curves of different bands is zero (unlike the method by Garrido).

We prefer to make use of this method, as it uses the variability in seven filters (while Garrido’s method only makes use of one colour and one phase difference). As it turned out, for both stars, we observe no phase difference at all in the seven filters. This is quite a surprise, since one expects to have severe phase differences due to non-adiabaticity. However, the data are of very high quality and leave no doubt that the phase differences are zero. In that respect,

it is better to use as many amplitude ratios as possible to derive the degree of the mode. The work of M. Van Loon consisted of several steps:

1. she translated the code of Heynderickx, which was written in Pascal, to C++,
2. she included improved numerical interpolation tools to calculate the derivatives of the functions (such as the flux and the limb darkening function) with respect to the effective temperature and the gravity,
3. she cross-checked if her results were compatible with those by Heynderickx for a large number of  $\beta$  Cep stars,
4. she added to the code the grid of stellar atmosphere models for the temperature range of the  $\gamma$  Dor stars.

For all three frequencies in both stars, the study favours very strongly the solution  $\ell = 1$ . All other  $\ell$ -values lead to amplitude ratios very different from the observed ones. These results remain to be confirmed, of course, preferably by spectroscopic studies, but they do help to discriminate between future excitation models for the  $\gamma$  Dor stars. We remark that the models by Guzik et al. (2000) imply the excitation of mainly  $\ell = 1$  modes, which is thus compatible with our observational results.

## 6. Future prospects

There are a number of future projects in the pipeline, both observational and theoretical. We mention here that a large observational campaign is being organized and performed by P. Mathias & collaborators. It consists of photometric and spectroscopic observations in the Northern Hemisphere. This, together with our spectroscopic study with Euler from La Silla for the Southern stars and our photometric study with Mercator from La Palma should allow us to constrain the observational behaviour of the  $\gamma$  Dor stars with high precision during the forthcoming years. Moreover, the observational results will allow a critical confrontation with the theoretical works that are currently being worked out (Löffler 2002; Wu, 2002 and maybe others).

## 7. Acknowledgements

We are thankful for the warm and generous hospitality of the researchers and staff in Cape Town and Sutherland.

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## Discussion

*Breger:* Could you comment on the high  $\log g$  value ( $\log g = 4.49$ ) at  $T_{eff} = 7000$  K which you derived from Geneva photometry? It appears very high and the star should not be below the ZAMS.

*Eyer:* In the light of HIPPARCOS data, Pierre North checked the  $\log g$  values given by the photometric calibration by Künzli et al. (1997) for a sample of  $\delta$  Sct stars. Indeed, the estimates of  $\log g$  seem affected by a systematic trend and to be too large by about  $\log g = 0.2$ . The source of this bias is neither understood nor identified but is under investigation.

*Aerts:* I also point out that, in general, the determination of the effective temperature is much more accurate than the one of the gravity. This is true for every photometric system. For B stars, the typical uncertainty of  $\log g$  is 0.2 – 0.5, even for bright stars.

*Balona:* 1) How can you tell if a singly-periodic star may not be a close binary rather than a  $\gamma$  Dor star?

2) You mentioned that two  $\gamma$  Dor stars do not show a variation of phase with waveband. This is rather strange since one would expect such a variation owing to non-adiabatic effects. Can you comment?

*Eyer:* 1) If the light curve had a sinusoidal shape (with minima of equal depth) the star was accepted as a  $\gamma$  Dor star variable.

We also looked at the colour variations, but for unambiguous answers we will have to wait for the spectroscopy results.

2) Yes, I agree, that is what we expected. But that is NOT what the stars are telling us. We clearly find that there is no phase difference for the two stars, of which we have numerous high-quality Geneva photometry.

*Handler:* With the increasing number of  $\gamma$  Dor candidates (17 in 1995, > 140 in 1999) and the increasing interest in these stars it has become very difficult to keep the  $\gamma$  Dor database up to date. I'd therefore like to encourage everybody to communicate their new discoveries to me for immediate inclusion in the  $\gamma$  Dor Master list. Simply send an e-mail to gerald@sao.ac.za. Thank you for your help to keep the database up to date.

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